Spectrum management and policy

A PolicyTracker e-book

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Introduction

In this short e-book we have tried to explain the key policy debates in spectrum management and put them in context.

At a cross roads, it is easier to choose left or right if you know what happened to previous travellers. Spectrum management has taken many cross roads and we have tried to explain the consequences of the choices made.

Why have most countries been reluctant to allow the winners of spectrum auctions to pay in instalments? The answer is the 1996 Entrepreneurs auction in the USA, where many winners defaulted (see chapter 3).

Why the current interest in spectrum sharing? Because market mechanisms have not delivered the dynamic competition which many hoped, as explained in chapter 2.

Rather than list events and facts we have tried to explain *why* spectrum policy has evolved. We hope this is more interesting and provides a useful introduction to newcomers.

But not everyone will agree with our explanations and short narratives are necessarily selective. So we hope experts will also read our e-book and use the comments section on the online articles to widen the debate.

Chapter 1: Spectrum management

It's how you call for help at sea and how air traffic controllers stop plane crashes

What is spectrum management and why is it important?

Let's start with the who rather than the what.

Who are spectrum managers? The people who are in charge of a nation's airwaves, and they usually work for arms-length government agencies known as regulators, like Ofcom in the UK or the NCC in Nigeria.

But what do they do? Look at regulators' websites and you'll struggle to find a definition of spectrum management, so here's mine: it's *controlling the airwaves for the benefit of society*.

But this simple definition raises as many questions as it answers:

1. Do we need to control spectrum?
2. If so, why?
3. What are these benefits?
4. Why might they not be realised?

The benefits of spectrum management

The third question is probably the easiest, so let's start with that. Spectrum is the raw material for a wide range of commercial and non-commercial services. Mobile phones are an obvious starting point: having moved from the hands of the privileged few in the early 1990s to near-ubiquity within 15 years. Radio broadcasting did the same in the late 1920s, as did TV in the 1950s and satellite services from the 1980s.

These are the three titans in the profit-making sector, but non-commercial uses are equally important. Safety of life services depend on it, it's how the police and fire brigade co-ordinate their services. It's how you call for help at sea and how air traffic controllers stop plane crashes. The military could not guarantee national safety without using spectrum for communications, radar and weapon control.

…in the early 1990s people started to ask whether regulators needed to expert so much control

Other commercial services do not directly save lives but are very valuable to society. Our knowledge of weather and global warming relies on spectrum to observe the earth from space and to run networks of terrestrial sensors; in the medical sphere devices like hearing aids and heart monitors all need access to the airwaves. We are trying to conserve energy in our homes, through smart cities and though better management of utilities: many of these services rely on spectrum.

And how is culture passed from one generation to another? Our experience of drama, films, music, literature and art in general come largely though TV and radio, although the internet is of increasing importance. Spectrum is crucial to the delivery of all three via terrestrial TV, satellite or mobile. Crucially, TV is also the most trusted source of political information.

The threats

So spectrum has a lot of important uses but what could stop this potential being realised?

Figure 1: Interference on a digital TV

Interference is the first hurdle. Services operating on the same frequencies can cancel each other out. For example, if two radio stations in neighbouring towns both broadcast on 95.5 FM, midway between the two locations the resulting mess would be unlistenable!

'Benefitting society'? Meaningless! that's anything you say it is!

So how do we prevent interference? The simple answer is making sure that several people do not try to use the same – or similar – frequencies at the same time in the same place. In our example, 95.5 FM should not be reused in two towns so close together.

Efficiency is the second issue. Similar types of services need to be grouped together or the spectrum would be used inefficiently. If television's "high power high tower" transmitters were to operate in the same band as mobiles – based on many low power transmitters reaching only a few kilometres each – phones would not work for hundreds of kilometres around the TV transmitter. On the fringes of the TV reception area mobile use would create interference for viewers. Place them in separate but adjacent bands and the huge area around the TV transmitter can be used for mobile.

This doesn't just apply to individual counties. A TV transmitter in Luxembourg could sterilise large areas of Germany, Belgium and France, giving spectrum management a necessarily international dimension.

Spectrum management: the how questions

To get the most out of the available spectrum it clearly needs some intervention. But how much and what sort are questions which have dominated policy discussions for decades.

Could the market, not regulators, decide who got what spectrum?

The obvious answer is that experts should decide how to manage services to promote efficiency and prevent interference and then co-ordinate this with colleagues in neighbouring countries. This is what happened from the 1920s onwards and still does to some extent, with the International Telecommunications Union (ITU) as the forum for global cooperation.

But in the early 1990s people started to ask whether regulators needed to expert so much control. Could the market, not regulators, decide who got what spectrum, echoing the privatisation of fixed line telecoms and other utilities? This is known as spectrum liberalisation and is covered in more depth in the next article of this series.

The answer to the first question, do we need to control spectrum, is yes, but the extent to which this is needed, and the way it should be done is an ongoing debate among the spectrum management community. And that debate is what we cover here at PolicyTracker, through our newsletter, research and training courses.

Does politics come into this?

My definition of spectrum management was “controlling the airwaves for the benefit of society” and I expect the final word raised some hackles: “‘Benefitting *society*‘? Meaningless! that’s anything you say it is!” Decisions about what benefits society are made in the realm of politics in a power struggle between politicians, citizens, experts, companies and various interest groups. Spectrum management decisions are often justified on technical grounds, but that is rarely the whole story.

There may be a marginal (and arguable) spectrum efficiency benefit in moving broadcasters out of 700 MHz and 800 MHz to make way for mobile services but the driver for these decisions is the perceived economic benefits of improved mobile broadband. Politicians decided the impact on broadcasting and associated industries was a price worth paying.
Many spectrum decisions are about future economic benefits as much as technical issues and we assess where the balance lies in the articles which follow.

Chapter 2: Spectrum policy

Are the airwaves the property of the state? Or private property, like land? Or something we all own?

What approach to spectrum policy will deliver the most benefits? The answer to that question has changed over the years, moving from command and control to liberalisation and most recently to an emphasis on spectrum sharing. Why has opinion shifted?

Turn the clock back to the start of the twentieth century and the issues that dominate spectrum policy debates are already emerging. From the 1880s the work of Hertz, Tesla and Fessenden and others established the scientific basis for communication using electromagnetic waves and this was commercialised most successfully by Marconi from 1894 onwards.

Spectrum policy: the state wants a role

But there was always pressure from agencies of the state to control the use of the airwaves. In the United Kingdom the government did not want radio transmitters to be used by spies. So the Wireless Telegraphy Act was passed in 1904 requiring anyone with a transmitter or receiver to have a licence.
In the United States, the Navy made several attempts to control the airwaves because amateur users were interfering with communications to ships. However, three bill proposals were rejected because lawmakers were concerned about giving so much power to the state.

This state power over the airwaves was the birth of is now called the command-and-control approach. But the commons approach was there as well. The early radio amateurs were sending signals through the air. As governments did not restrict the amount of air we can breathe, the amateurs saw no reason for them to control this other use of a free natural resource.

Figure 2: An early ham radio station

Many radio amateurs saw spectrum as a ‘commons’: a free public space which could be used by anyone without charge or restriction. This approach to spectrum management continues today, most famously in 2.4 GHz, the

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main Wi-Fi band where permitted powers are so low that the danger of interference is very small.

…mobile companies were developing multi-billion-dollar businesses based on spectrum awarded for free

But not all amateurs were not content with unpaid experimentation, and in the United States, as the 1920s progressed the radio industry boomed, and many went from merely sending messages to playing music, talk-based entertainment and even forms of advertising. Despite operating out of garden sheds, they were becoming what we now know as radio stations.

To be commercially viable these new stations needed certainty about their access to the airwaves. In short, they needed a licence, which would guarantee access for a defined period without interference. In the United Kingdom in 1920, Marconi, that pioneer of commercialisation, sought a licence from the military to transmit music. It was granted, and then withdrawn, and then awarded again when the generals were overruled by the government.

The current spectrum management debates are already there. Are the airwaves the property of the state, like airspace or territorial waters, as the military believed? Or are they private property, like land? Or are they something that we all own, like air or common land? Pioneers tended to give yes or no answers, but as the spectrum policy debate has progressed, the airwaves now tend to be regarded as all of the above, depending on the circumstances.

The era of broadcasting chaos

The command and control approach – where licences would be issued by agents of the state – was set in stone in 1926, in what became known as the era of broadcasting chaos.

The US government refused a licence to the Zenith Radio company who took them to court and won. The ruling meant that the government had no power to restrict radio stations' use of the air waves: anyone could get a licence. This was the height of the radio boom and more than 200 stations were set up in the next 9 months. Stations turned up the power to blast out their neighbours and started broadcasting on whatever frequencies they chose. It was chaos: commercial stations interfered with each other and with emergency communications.

Other nations were watching closely and the received wisdom was that you could not trust the commercial sector to police itself. The airwaves needed to be regulated and the US soon brought in laws confirming the right of the state to set the technical parameters for licences and refuse them if necessary.

And this command and control approach was how almost all licences were issued until the 1990s, generally at zero cost to the user. It was the arrival of mobile telephony that changed minds: these companies were developing multi-billion-dollar businesses based on spectrum awarded for free. It was time that spectrum was opened up to market forces in the same way that the rest of the telecoms market had been liberalised in the previous decade.

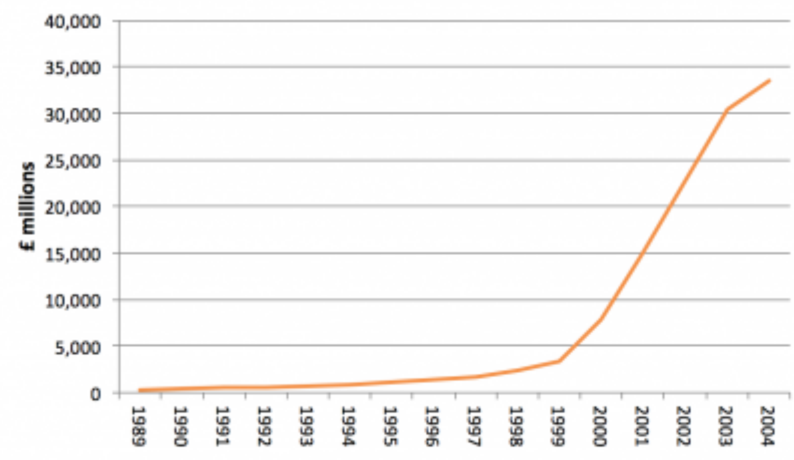

Figure 3: Vodafone Group turnover (Company launched mobile services in 1985 based on free 900 MHz spectrum)

Let licences be traded freely and the price mechanism will ensure the most efficient use of the airwaves, Coase argued.

For inspiration policy-makers turned to a 1959 paper by the US economist Ronald Coase, which had been largely ignored. He argued that the era of broadcasting chaos had been caused by the failure to give broadcasters clear property rights like they might have had in land. Spectrum can be treated like any other asset – if you give a broadcaster the legal right to make commercial use of 200-210 MHz they can protect this right by going to court if necessary, just like a farmer could take legal action to stop a neighbour's cows straying onto their land.

Give spectrum users those rights and the market, not regulators will determine the best use of the spectrum. Let licences be traded freely and the price mechanism will ensure the most efficient use of the airwaves, Coase argued.

So from the mid 1990s onwards market mechanisms became increasingly important, particularly for mobile spectrum. The liberalising agenda was:

- Sell spectrum where possible
- Create licences that are technology and service neutral and allow for change of use
- Allow those licences to be traded in a secondary market
- Boost spectrum efficiency by sharing frequencies where possible

With these mechanisms in place, in theory ownership of the airwaves should naturally flow to the users or uses that can extract the highest value.
Not all these measures were adopted globally – the most popular were technology neutral licensing and spectrum auctions. The United States led the field, with the United Kingdom following and the European Commission making liberalisation the cornerstone of its developing spectrum policy from the early years of the new millennium. Within a few years all EU countries were required to allow trading and practice technology neutral licensing in the most valuable bands.

The effect of the capacity crunch on spectrum policy

It was a tacit admission that liberalisation alone could not deliver

However, around 2009 there was a major setback for the liberalisation project. The iPhone had launched in 2007 and demand for mobile data had grown exponentially leading the mobile industry and regulators to conclude that there was a pressing need for more spectrum to prevent network overload.

Figure 4: Early iPhone

The collective response did more than anything else to signal the limits of spectrum liberalisation. Mobile companies did not directly seek to buy spectrum from other users, like broadcasters and the public sector, because in most countries this would not be practically or legally possible. This was true even in the most liberalised markets, such as the United States.

Regulators did not tell mobile operators to source this spectrum through the market. They tried to reallocate the airwaves at a national level as well as sought international solutions by forming common policies at the regional and International Telecommunication Union (ITU) levels.

It was a tacit admission either that liberalisation alone could not deliver, or that it was inherently a slow process, unfit for its biggest challenge so far.

A less dramatic failure for liberalisation has been the limited impact of spectrum trades in Europe. Trades have been allowed in most European countries for over a decade but there have been no voluntary trades in the highest-value mobile bands, unlike the USA or Australia.

Spectrum sharing

As confidence has diminished in the ability of liberalisation alone to deliver a dynamic and competitive market so policymakers' focus has shifted to encouraging spectrum sharing. If pure financial gain is impractical or commercially unattractive as a means of encouraging incumbents to give up their spectrum, then regulators can require the sharing of spectrum where this will not damage existing services.

The sharing of unused portions of TV spectrum – known as TV whitespace – is one example. This hasn't been successful in the developed world because digitisation and the repacking of TV signals has reduced its technical potential, but there are higher hopes for the developing world.

Other possible sharing initiatives are Licensed Shared Access (LSA), a legally standardised technological solution which allows sharing agreement promoted by time, frequency or geography and has the backing of the US and the European Commission. It is particularly applicable to 2.3 GHz in Europe, but has hardly been used so far.

…command and control has not disappeared

The big hope for sharing is the CBRS initiative in the US. This is a three tier approach to spectrum usage, where incumbent users have some spectrum, but other guaranteed rights are auctioned as priority access licences (PALs). Spectrum not being used by PALs – as well as some additional spectrum –

is available for opportunistic access governed by a database to prevent interference to the other two layers.

Conclusions

We have argued that there have been three paradigms in spectrum policy: the first was command and control, which dominated until the 1990s. This was followed by the use of market mechanisms, mainly for mobile spectrum. The third paradigm started around 2015 and has focussed on harnessing the potential benefits of spectrum sharing.

While this analysis shows how policy thinking has changed, we should remember that command and control has not disappeared – it remains the dominant approach for public sector and lower value spectrum. Neither has the use of market mechanisms disappeared: it is used almost globally for mobile licences. Sharing approaches are in their infancy and their likely success will be measured over the next decade, starting in earnest with the launch of CBRS in 2019.

Chapter 3: Spectrum auctions

Auctions fulfil the same comparative function performed by a beauty contest, in theory allowing the market to test a business plan

When did spectrum auctions start being used and why? What are the pros and cons of various auction formats? When have spectrum auctions gone wrong? Should they still be used?

Until the 1990s almost all licences were issued not through spectrum auctions, but using what was is known as the command and control approach. An enterprise seeking access to spectrum would ask the government for permission, which was granted if no one else was using the frequency. There was usually no charge, but there were specific restrictions on power and technology to prevent interference with other users.

In the 1990s, as more spectrum was needed for commercial and non-commercial services, questions began to arise about whether command and control was out of place in a world where spectrum usage underpinned high-growth sectors like mobile and computing. The idea of spectrum liberalisation took hold, and with it, the concept of spectrum auctions.

The dawn of spectrum auctions

The key principle of spectrum liberalisation is that users should pay for their spectrum in the same way they would pay to use any other asset, giving them the incentive to use the spectrum efficiently.

Figure 5: Ronald Coase (University of Chicago Law School)

The idea of using price to allocate frequencies was floated by economist Ronald Coase in 1959. His article, "The Federal Communications Commission," provided the foundation for the development of the "property" school of spectrum management. In the USA in 1993, the Clinton Administration was looking to raise revenue and other means of distributing spectrum licences, such as through comparative hearings or lotteries, had failed. The US Congress temporarily authorised the Federal Communications Commission (FCC) to hold a spectrum auction in 1994, and its success led lawmakers to make such auctions mandatory in 1997.

Interest in auctions surged as the idea of applying economic theory to the use of the airwaves became increasingly popular. By 2000, it was inspiring a global array of liberalisation measures, among the most popular spectrum auctions. The US led the field, followed by the UK, with the European Commission making liberalisation the cornerstone of its developing spectrum policy from the early years of the new millennium. By the second decade of the 21st century, auctions had become the default assignment process for high-value spectrum, particularly for mobile licences.

Why use auctions?

The SMRA is the most widely used spectrum auction format

Prior to liberalisation, high value spectrum was often awarded through the so-called "beauty contest" ("administrative assignment" is the official term). This is a tendering process where competitors submit bids in which they try to persuade regulators that they should receive a given block of spectrum. The bids are evaluated according to a set of criteria that reflect whatever a regulator's policy goals are. By contrast, in an auction, the only criterion is the price bidders are willing to pay.

But beauty contests have three main problems. They are slow, insufficiently transparent (paving the way for lawsuits), and provide an incentive for winners to over-promise and under-perform. Ditto for lotteries, which the FCC used in 1982 and which failed to speed things up while creating even more serious problems.

Auctions, on the other hand, fulfil the same comparative function performed by regulators in a beauty contest, in theory allowing the market to test an entity's business plan. They are also quicker and offer a huge windfall for government treasuries.

The different types of spectrum auctions

Today, commercial spectrum auctions generally use the following formats or variations thereof:

- Simultaneous Multiple Round Auction (SMRA), whose distinguishing feature is that it is selling the actual licence the bidder will receive.
- Ascending Clock Auction (ACA),in which bidders indicate how many generic licences types they want. The actual frequency ranges are then assigned to the winners either by the regulator or by a further bidding process.
- Combinatorial Clock Auction (CCA) where the primary stage is the same as an ACA, followed by a secondary stage where participants can bid on alternative combinations. This is usually a second price auction, so the winners pay the highest value that other bidders offered for their package.

The SMRA is the most widely used spectrum auction format, and was adopted by the US in 1990s. One advantage of the SMRA is that winning bidders get individual licences to operate in the specific frequency ranges that they were bidding on. By contrast, an advantage of the ACA is that it allows competitors to seek packages of similar spectrum rather than being "stranded" on just one frequency.

But the times may be a-changing. The philosophy behind CCA is to enable bidders to bid for different combinations of spectrum blocks, and if the value of a particular band depends on how much the bidder obtains of different bands, the combinatorial bid can express the true value of the spectrum, according to Copenhagen Economics consultant Henrik Ballebye Okholm. In theory, CCAs also foster spectrum efficiency because bidders can only win specific spectrum if it's worth more to them than rivals.

The format is viewed as very complex but the hope was that this complexity would be balanced by better outcomes, says Dennis Ward, a former Industry

Canada auctioneer and now an independent consultant.. Several spectrum administration chose the format around 2008-2013, including Switzerland. Its 2012 auction of spectrum in the 800 MHz, 900 MHz, 1800 MHz, 2.1 GHz and 2.6 GHz bands raised CHF 996.3 million (€824.7 million) but its skewed results showed the downside of CCA. Operators Orange and Sunrise won 160 MHz but Sunrise paid €270 million more. In fact, Sunrise even paid €100 million more than Swisscom, which won 255 MHz of spectrum. This was because Sunrise's rivals' second prices were dramatically lower than their first prices.

Are mobile operators spending so much money buying spectrum licences that they can't afford to build out networks?

	Orange	Sunrise	Swisscom
Total spectrum won	160 MHz	160 MHz	225 MHz
Price in €	129M	401M	299M
€/MHz/pop	0.103	0.320	0.150

Figure 6: Winners of the 2012 Swiss CCA

Another example of an auction gone awry were the 1996 FCC wireless personal communications C-block auctions. They were open only to entrepreneurs, who could take advantage of 10-year instalment payment plans at government-subsidised borrowing rates. Bidding credits were also made available to designated entities. The result, as laid out in a 2005 Congressional Budget Office paper, was that "the initial C-bock auctions put relatively few licenses into the hands of bidders that could actually pay for them." A large proportion of firms over-bid, then defaulted or went bankrupt: the Entrepreneurs auction led to unused airwaves rather than assigning spectrum to the most efficient users.

Some countries are now shifting to simpler formats such as SMRA or Sealed Bid Combinatorial Auction (although other administrations continue to opt for the CCA).

Policy debates

Auctions, which in recent years have been considered the best, most efficient, mechanism for awarding spectrum, are now the subject of a range of policy debates.

One major discussion centres on whether auctions lead to overpriced spectrum. A 2017 study by PolicyTracker for the European Commission showed an association between poorer 4G network availability and higher auction prices, suggesting an impact on investment. The question here is whether mobile operators are spending so much money buying spectrum licences that they can't afford to build out networks and expand coverage.

Another controversial issue is whether high prices for spectrum adversely affect communications markets. Here, the question is the extent to which spectrum prices are a sunk cost. The mobile sector generally believes that steep spectrum prices hurt consumers and that efforts to maximise revenues from auctions can harm the wider economy. A traditional view in economics is that sunk costs are a precondition to market entry and do not affect charges to consumers. If this is correct, there is no problem with using an

auction design that raises more money for the government. For those of the other view, higher prices would result in adverse consequences.
Hanging over these disputes is the overarching question of whether it is possible to boost competition without spectrum auctions.

William Webb argues that auctions have become litigious with uncertain outcomes that can slow investment

Former Ofcom chief technologist, Professor William Webb, argues that auctions have become litigious, time-consuming to arrange, burdensome for the regulator and industry, and with uncertain outcomes that can slow investment. A better mechanism might be for regulators to directly assign equal amounts of spectrum to incumbents. Counterarguments are that such assignments forego auction fees and could hamper new entrants.

Another viewpoint is that the conventional approach to licensing spectrum has not achieved coverage and rollout policy objectives. Gerárd Pogorel, emeritus professor of economics and management at Telecom ParisTech, for example, notes there appears to be momentum to explore innovation in assignment processes and conditions, such as auctions on coverage obligations as opposed to frequency fees with coverage obligations, or even fee waivers to favour investments.

Chapter 4: 5G spectrum

The lower bands are likely to deliver speeds marginally higher than 4G networks, but are needed for wide area coverage.

5G is the first mobile generation to use high frequencies like 26 GHz. This makes it potentially much faster with lower latency

5G will be able to use all the existing 4G bands like 900 MHz, 1800 MHz, 2.6 GHz and 3.5 GHz but the term "5G spectrum" is commonly used to describe frequencies far higher than those that are currently used. These are generally called the mmWave bands, such as 24 GHz, 28 GHz and 40 GHz.

One of the great achievements of 5G is opening up these higher frequencies previously thought unsuitable for mobile communications. It allows much faster data rates and better responsiveness – theoretically speeds up to 1 Gbps and a latency of 1 millisecond.

Harmonising spectrum enables economies of scale and facilitates cross-border coordination and roaming for end users. Thus, countries and industry stakeholders around the world are trying to agree on a series of bands suitable for 5G, in a bid to create a 5G global economy.

With slight differences between the three ITU regions (Europe & Africa, Americas, and Asia), 5G spectrum can be divided into two ranges: sub 6 GHz and above 6 GHz.

Communication service providers, however, will need to balance and combine both ranges for optimal coverage, capacity and quality of service.

5G spectrum: sub & above 6 GHz

Sub 6 GHz spectrum, with a spread of 450 MHz to 6,000 MHz, promises to offer both coverage and capacity. Within this range, the lower bands (under one gigahertz) are likely to be used for wide-area and indoor coverage, as well as Internet of Things (IoT).

The lower bands are likely to deliver speeds marginally higher than the current 4G networks, but are needed for wide area coverage.

Mid-band frequencies (2000 MHz to 6000 MHz) offer a compromise between the broad coverage enabled by lower frequencies and the higher capacity supplied by higher bands. Here, the C-band (3300-4200 and 4400-5000 MHz) has emerged as prime frequency.

In line with allocation plans from many countries, the 3300-3800 MHz band will be the primary 5G band with greatest potential for global harmonisation.

From an economical point of view, this band has many benefits because it allows the deployment of 5G antennas on existing macro-cellular or small-cell grids without requiring new cell sites.

Above 6 GHz the current focus is on mmWave between 24 GHz to 86 GHz. (Technically speaking mmWave is above 30 GHz but it has become a convenient shorthand!)

26 GHz is one of the most widely-supported 5G candidate bands and has been already harmonised within the EU.

Typically, these mmWave bands are seen as 5G spectrum: larger the frequencies, and larger bandwidths giving the ability to support extremely high data rates required for ultra high speed broadband – know as eMBB – and use cases like manufacturing or virtual reality.

The major drawback of mmWave spectrum is very small coverage areas and poor building penetration. Propagation for these frequencies often requires line-of-sight (LOS) conditions between the base station and device.

However, many researchers now argue that these challenges can be overcome by new technologies, such as beamforming and massive MIMO. The World Radiocommunication Conference 2015 (WRC-15) paved the way for the future development of IMT on higher frequency bands by identifying several frequencies for study within the 24.25-86 GHz range. After four years of studies, the ITU World Radiocommunication Conference (WRC-19) will be tasked later this year with establishing international agreement on 5G bands above 24 GHz.

26 GHz vs 28 GHz

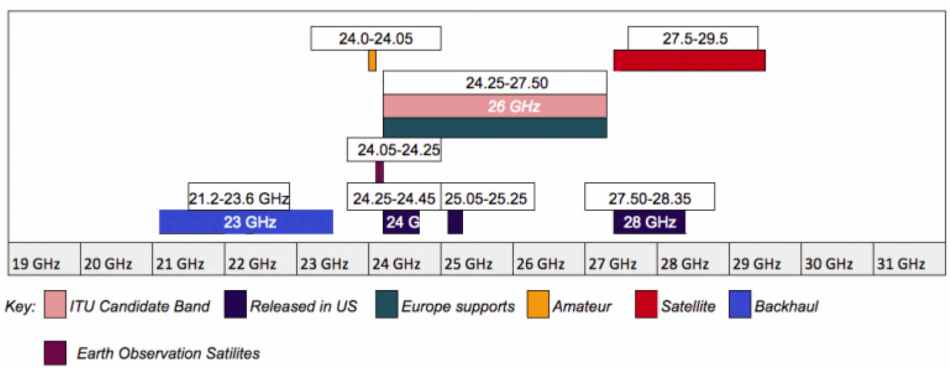

Figure 7:Potential 5G bands and other uses between 20-30 GHz

In the mmWave range, 26 GHz and 28 GHz have emerged as two of the most relevant bands. The latter (27.5-29.5 GHz) is not included in the WRC-19 Agenda Item 1.13, but the global marketplace is driving the need for additional 5G spectrum.

Countries like USA, South Korea, Japan and Canada are heavily backing this band for 5G services. The 28 GHz band has also seen its first commercial rollouts, with Verizon using this frequency for Fixed Wireless Access (FWA). Meanwhile, 26 GHz (24.25-27.5 GHz) is one of the most widely-supported 5G candidate bands under discussion at WRC-19 and has been already harmonised within the EU, which means that European countries must put it to effective use by the end of March 2020.

Despite this support, a major debate is taking shape for WRC-19 over concerns that mobile use of the popular 26 GHz band for 5G could cause harmful interference to earth exploration and radio astronomy services in 23.6-24 GHz.
Delegates will have to decide at WRC-19 on the technical conditions of the 26 GHz. If they adopt a lenient approach, satellites used by the World Meteorological Organisation (WMO) and the body representing European

space agencies (ESA) could be affected.

In general, support for bands decreases as the frequencies increase

On the other hand, if regulators opt for more stringent conditions, 5G rollouts could be curbed. A number of stakeholders have been raising concerns about the difficulties of manufacturing chips that can operate on 26.5 GHz frequencies.

Reaching consensus on the protection conditions could be difficult. In this research note, we explain how the protection of passive services could affect the commercial prospects for 26 GHz and how this could affect operators' decision-making as they choose between this band and 28 GHz.

Other 5G frequency bands

Of the 11 possible bands between 24-86 GHz, 26 GHz starts with a clear advantage whilst 32 GHz is the least favourite to become a 5G candidate band. There was reasonable support for 32 GHz, but this fell away in autumn 2018 when Europe and the relevant ITU study group withdrew its backing. Support for higher bands –71-76 GHz and 81-86 GHz– is fairly limited

Three bands around 40 GHz (37-43.5 GHz), however, have as much support as 26 GHz. Different regions support different sections of the 40 GHz range but the idea is that WRC-19 would agree on a tuning range approach so it would allow adjacent bands to be supported by the same equipment. That approach is particularly relevant in 40.5 -43.5 GHz due to complementary developments in other regions in adjacent bands. That makes approval as 5G candidate bands at WRC-19 likely.

In general, support for identification of bands for IMT decreases as the frequencies increase. The 66-71 GHz range has a reasonable chance of an IMT identification as long as there is also access for other technologies, including unlicensed services.

Support for higher bands –71-76 GHz and 81-86 GHz– is fairly limited. Only China and US regulator the FCC are pushing to get an IMT identification in those bands.

Overall, WRC processes are highly unpredictable but PolicyTracker's guide can help you identify areas of consensus and disagreement in some of the items being discussed at the forthcoming World Radio Conference.

Chapter 5: 5G verticals

The latest mobile generation differs from its predecessors because as well as providing connectivity it relies on finding business in new markets such as industry, transportation and healthcare: known as 5G verticals.

Supporters believe the combination of 5G and IoT will be transformational, fostering a fourth industrial revolution.

Industry verticals, such as the automotive, healthcare or electronics sectors, are widely considered as central to 5G take up, at least initially. This note explores why 5G verticals are viewed as so important, and whether they can deliver what is expected of them.

Historically, mobile communication has been used by individuals. Mostly these individuals have been consumers, using a mobile device for their own interests. At other times they have been business users with a device issued to them by their employer. In the latter case, their usage was dictated by their jobs.

In the initial analogue days of the mobile industry in the 1980s, business users drove the marketplace but were latter surpassed by the mass adoption of mobile phones by consumers. That process started with the advent of GSM digital phones, also known as 2G, in the early 1990s. The consumer continued to hold sway through the arrival of 3G in the 2000s and afterwards 4G in the 2010s.

Figure 8: Factory robots unloading glass (ICA Plants)

Now the mobile industry faces a discontinuity. 5G will be different, say experts, because businesses will be back in driving seat. But this time the emphasis is less on connections to individuals than enabling objects or industrial processes to communicate.

This trend crosses over with another shift for the mobile industry, the Internet of Things, or IoT. Supporters believe the combination of 5G and IoT will be transformational, fostering what is sometimes termed a fourth industrial revolution.

…self-driving vehicles are often tipped as a prime market

Use cases

5G's extremely high bandwidth will be central, as well as another feature of the new technology: its low latency, which means the ability to send a large amount of data with a minimal time delay.

Low latency has the potential to enable 5G to support various use cases. Oft quoted examples are from healthcare: a western surgeon remotely conducts surgery on a patient in the developing world. Or the mining sector, where an engineer could manoeuvre heavy equipment, such as large trucks or diggers, in a remote part of Australia from their comfy office chair in Sydney or Melbourne. Low latency will be crucial to some, but not all 5G applications.

This theorising about 5G verticals is also based on another, less optimistic, supposition: that consumers will not be attracted in sufficient numbers to the new technology, which initially will retail at relatively high prices, for the mobile industry to make a healthy return on investment. Current 4G speeds are sufficient for most applications, the theory goes, and consumer demand for 5G will come only later when prices drop.

This vision for the 5G marketplace is supported not just by the mobile industry, such as MNOs or handset and network equipment vendors, but is also the standard view of consultants and analysts. Significantly it has also been bought into by governments. Wealthy countries, such as the US and those in the European Union see backing for 5G verticals as a means to maintain prosperity while many in other parts of the world, such as Asia, see a means to climb the prosperity ladder by making national industries more competitive.

And what about industry? After all, they are the people who will deploy 5G (and pay for it).

The road ahead for 5G verticals

Commitment by industry is of course vital. Interest varies by sector. Autonomous, or self-driving, vehicles are often tipped as a prime market. Yet the automotive industry faces significant challenges to overcome in its pursuit of self-driving vehicles.

Obstacles include fragmentation, both in terms of technology being deployed (C-V2X versus DSRC), as well as choice of radio frequency. In addition, it is unclear who will foot the bill to build the roadside infrastructure needed to support such services.

More promising might be the application of 5G in a factory setting. German giant Bosch has talked about 5G as a means of enabling productivity increases worth trillions of euros. Certainly using 5G instead of fixed fibre cabling would enable greater flexibility for manufacturers, enabling factories to become smarter.

So how to enable such a vision? One model is setting aside part of the spectrum for industry to use on a localised basis. This would enable companies to acquire their own spectrum, so bypassing the traditional mobile industry, an outcome which alarms MNOs since they would earn little or no revenue from such an arrangement.

It's also possible a compromise model might emerge whereby a factory makes accesses unused spectrum on an MNOs' 5G network.

Some countries, including Germany, Japan, the Netherlands and Hong Kong, are backing the award of localised spectrum to verticals. But others who one might expect to go the same way, such as France and South Korea, have not, citing a lack of demand from industry. So the picture is mixed. One thing is certain about calling the outcome – technology predictions rarely pan out as the soothsayers yearn for, and never in a convenient timescale. That is also likely to be the case with 5G verticals.•

Some countries are backing the award of localised spectrum to verticals but others have not, citing a lack of demand

Chapter 6: WRC-19

…the ITU-R does not police the Radio Regulations; they are obeyed because every Administration has agreed to them

The International Telecommunication Union holds a World Radiocommunication Conference, known as a WRC, every three or four years. What do they do, why are they needed, and what is at stake at WRC-19?

Figure 9: Thousands of delegates attend WRCs (ITU)

Although countries administer their own spectrum policies, it is considered helpful for these to be internationally aligned to some extent. This is for two reasons:

- Prevention of interference between countries, known in the ITU context as Administrations. One country's radio transmissions (such as from a high-power service like terrestrial broadcasting) could cross borders and interfere with a neighbour's receivers (such as for a low power service like satellite downlinks).
- Harmonisation. If industry is sure that all or most Administrations will use a given band for a given service, then they can mass produce equipment. This can drive costs down, as well as allow for global interoperability and roaming.

UN Member States try to achieve this by agreeing on a set of Radio Regulations.
The Regulations define primary and secondary services for cross-border interference. If a service is primary then an Administration can use the spectrum, if it follows the technical rules incorporated into the Regulations by reference, without worrying about receiving interference from or causing interference to any other country.

The Regulations also govern orbital locations for satellites and the use of spectrum in space, an area where individual states are not sovereign.
World Radiocommunication Conferences (WRCs) are the only instruments

that can amend the Radio Regulations. These are convened by the radio division of the International Telecommunication Union, a specialized agency of the UN known as the ITU-R, every three or four years. WRCs are often held at the ITU-R's headquarters in Geneva but the next one, WRC-19, will take place at Egypt's Sharm El Sheikh beach resort, from October 28 to November 22.

Although Administrations may make proposals to a WRC on their own, it is considered more effective if they contribute to Multi Country Proposals

Voting is theoretically possible at WRCs, but in practice all decisions are made by consensus. This is because the ITU-R does not police the Radio Regulations; they are only obeyed because every Administration has agreed to them.

The WRC cycle

The need for consensus drives a four-year preparatory process that gives Administrations ample time to understand the issues, develop views, build coalitions, and ultimately prepare for compromises.

Each WRC contains an agenda item 10, which calls for the drafting of future agenda items. WRC-19, for example, contains over 30 agenda items and issues, some of which were the result of hard-fought negotiations that took its predecessor, WRC-15, right up to the brink of running out of time.

A first Conference Preparatory Meeting (CPM) is held the week after WRC. This divides the agenda items among the ITU-R's specialized Study Groups, which regularly gather experts sent by Administrations to understand issues gathered under groups of services.

For example, WRC-15 agreed to continue its previous work on allowing Radio Local Area Networks to use more of the 5150 – 5925 MHz band. In December 2015, CPM-1 delegated the issue to a sub-group of Study Group 5, which deals with terrestrial services.

Item 10, the agenda for future WRCs, often provokes fraught discussions

The Study Groups develop possible Methods, taking into account contribution from any interested party, that might resolve the agenda item. For 5 GHz RLANs, a Working Party of SG 5 studied its spectrum requirements, their potential impact on currently allocated services in a series of particular frequency bands, and finally identified some Methods to resolve the item. These Methods span from No Change, to changing some of the technical rules associated with particular sub-bands.

All of these Methods are collected in a CPM Report, which was put together at a second Conference Preparatory Meeting held in February this year. In parallel to the CPM process, individual Administrations will look at the issues and develop their own views. Although Administrations may make proposals to a WRC on their own, it is considered more effective if they contribute to Multi Country Proposals. There are six regional organisations that help coordinate these MCPs, each with its own set of working practices. They often send representatives to each other's meetings to better understand their positions.

For 5 GHz RLANs, it became clear during the WRC-19 cycle that there was no political support for any change in the 5250 – 5725 MHz and 5850 – 5925 MHz ranges, so the CPM Report only contains potential methods for relaxations of the rules at 5150 – 5250 MHz and 5725 – 5850 MHz.

Administrations and regional groups are now working to build support for their favoured methods.

It is likely that the most contentious items will be those that delegates least expect.

What's at stake

Administrations that ignore Regulations do not suffer harsh consequences, especially with respect to terrestrial services. Arguably the most important output of the WRC is its long iterative process of technical and political consensus-building that incorporates views industry and governments across the world.

But many countries, especially in the developing world, closely adhere to the Regulations, so the WRC process gives participants the opportunity to export its vision of the optimal use of spectrum across the world.

The mobile industry has often sought to take advantage of this by changing the Regulations' footnotes so as to "identify" a band for IMT, which is ITU-jargon for mobile broadband. WRC-19 promises to be no exception to this trend. The most popular band in the relevant agenda item (1.13) is the 24.25 – 27.5 GHz range, which plays a crucial role in most counties' 5G strategies. Administrations agree on the need to identify IMT in the band, but there have been vigorous discussions on the best way to prevent interference to the adjacent weather radars at 23.6 – 24 GHz. Satellite users and Wi-Gig proponents are also nervously watching discussions at 37 – 43.5 GHz and 66 – 71 GHz respectively.

The mobile industry is also on the defensive at WRC-19 with respect to the 28 GHz band. Satellite operators want to allow Earth Stations in Motion to transmit at 27.5 – 29.5 GHz as part of agenda item 1.5. But mobile operators are advocating strict limits on this to avoid interference to backhaul links, which operate under the already-existing fixed allocation

Agenda Item 10, the agenda for future WRCs, often provokes fraught discussions. The USA's failure to secure an agenda item on IMT at 27.5 – 28.35 GHz for WRC-19, for example, led to some politicians to advocate the US withdrawing funding for the ITU. Although at an early stage in development, the potential prospect of studying identifying different frequencies from 3.6 to 24 GHz for IMT at WRC-23 is already causing consternation among the bands' current users. Satellite users in particular are worried about repeating previous battles over potential IMT identifications at 3.6 – 4.2 GHz.

Some agenda items appear esoteric but have the potential to introduce difficult political issues. This includes agenda items 1.11, 7-A, 9.1-7, and 9.1, concerning spectrum for trains, reserving spectrum for non-geostationary mega-constellations, satellite terminals, and IMT at 4.9 GHz respectively. It is likely that the most contentious items will be those that delegates least expect. WRC-15 saw surprisingly easy agreement on spectrum for Global Flight Tracking, but long disagreements on apparently uncontentious future agenda items.•